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Analysis of health data from 10 years of Polaris submarine patrols

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Tansey, W. A., J. M. Wilson, and K. E. Schaefer. 1979. Analysis of health data from 10 years of Polaris submarine patrols. Undersea Biomed. Res. Sub. Suppl.: S217–S246.—Medical reports from 885 Fleet Ballistic Missile (FBM) submarine patrols (7,650,000 man-days) were analyzed. The data were categorized and compared with data obtained by medical personnel from surface fleet personnel (1,215,918 man-days) during a continuous 7–8 months' deployment of surface vessels in 1973. Surface fleet personnel had a higher illness rate in the categories of respiratory, traumatic, gastrointestinal, dermal, infections, and miscellaneous illness, and a lower rate in genitourinary, systemic (including mononucleosis), cranial, and neuropsychiatric illness compared to submarine personnel. Because of improved atmosphere control, a sharp decline in the level of submarine contaminants occurred between 1965–67. Reports from the 1968–73 period showed a decrease in: 1) respiratory; 2) ear, nose, and throat; 3) gastrointestinal; 4) cardiovascular; 5) urologic; and 6) general medical illness categories; the number of general surgery, orthopedics, dental, and eye illness cases was not affected. Neurologic and psychiatric disease showed the only increases in incidence for this period. The overall decrease in illness can be attributed mainly to the fall in the incidence of respiratory disease, known to be affected by reduced air pollution, and the decline in gastrointestinal illness. This decline occurred in a period during which the incidence of both classes of illness went up in the general population, according to the Health Interview Survey published by DHEW. The improvement of atmosphere control in submarines caused a substantial reduction in contaminants (a decline in tobacco smoking also occurred in this period), which led to a decrease in incidence of illness, particularly respiratory disease. No direct causal relationship between reduction in air pollution and reduction in the incidence of disease could be proven within the framework of this study, however.

epidemiology
atmosphere control
air pollution
submarine medicine

Since 1960 there have been well over 1000 *Polaris* submarine patrols. Each patrol report contains a medical section that is maintained at the Naval Submarine Medical Research Laboratory in Groton, Connecticut. These reports contain a wealth of information concerning the medical problems encountered during prolonged submergence. A *Polaris* submarine patrol is unique in many respects: the crew of 140 men are encased in a totally artificial environment for periods in excess of 60 days and are subject to the stresses associated with operating one of the most complicated pieces of machinery on earth.

The illness rate of submarine personnel during patrols is of significance for an assessment of the efficacy of pre-patrol screening of personnel. Moreover, it is important to know whether exposure to the submarine environment results in specific disease patterns and to what extent the latter may have been influenced by the improved control of submarine atmosphere contaminants that took place during the last decade. These factors deserve even further attention when the additional demands that will be placed upon *Trident* submarine crews are considered.

In this study the health data collected from the medical reports of 885 patrols from the years 1963 to 1973 are analyzed and compared with statistics collected from a similar population in the surface component of the Navy.

METHODS AND MATERIALS

The medical sections of 360 patrol reports from 1963–1967 were previously reviewed by Wilken (1969): these data were used, together with information obtained from 525 additional medical patrol reports for the years 1967—1973. Calculations of man-days were based on the assumptions of 140 men per crew and a 60-day patrol. Only those illnesses occurring at sea in the environment of the submerged submarine that resulted in at least one sick day lost from duty have been included in this report. All diagnosis and treatment decisions had been made by on-board physicians.

A total of 1685 cases were treated aboard submarines from 1963 to 1973, accounting for 6460 days lost from duty. Although those cases that resulted in transfer at sea or death were not included in the tabulations. they are mentioned under the appropriate headings. In Table 1, comparisons were made with the illness rates in the surface fleet. These data were collected partly by medical officers and partly by corpsman during a continuous 7–8 months' deployment of three types of surface vessels: destroyers, destroyer escorts, and guided missiles, and

TABLE 1

ILLNESS RATE AND RATE OF DAYS LOST IN SUBMARINE AND SURFACE FLEET

	Submarines 1968–1973		Surface Fleet 1973	
	Illness Rate	Rate of Days Lost	Illness Rate	Rate of Days Lost
Respiratory	0.027	0.078	0.13 *	0.14*
Trauma	0.036	0.16 *	0.10 *	0.13
Gastrointestinal	0.035	0.12	0.09 *	0.19*
Dermal	0.022	0.045	0.02	0.04
Infection	0.014	0.041	0.06 *	0.08*
Genitourinary	0.014	0.046*	0.010	0.01
Systemic	0.010*	0.057*	0.004	0.00
Cranial	0.013*	0.040*	0.003	0.00
Neuropsychiatric	0.012*	0.042*	0.006	0.01*
Miscellaneous	0.001	0.01	0.01 *	0.02*
Total	0.184	0.64	0.433*	0.62

Total man-days for submarines = 4,410,000; for surface fleet, 1,215,918. *Differences between submarine and surface fleet significant at the 5% level or better.

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RESULTS

I. Comparison of illness rate

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were classified according to the format of the standard monthly outpatient morbidity report (NavMed 6300-1). The submarine data were classified in the same manner as the surface ship data. The following rates were computed: illness incidence by specific category and total illness incidence (number of new cases per 1000 men per day at sea) and rate of days lost from duty by specific illness category and total rate of days lost from duty per 1000 men per day at sea. The two sets of data (submarine and surface vessels) were thus theoretically comparable, except that the submariners were exposed to an atmosphere that was almost entirely artificial and controlled. Both populations were selected in that they received the same health screening upon entrance into the Navy and both were isolated at sea for extended periods. Although certain other differences in the populations do exist, the surface population served as a reasonable control group. The surface data consisted of 334 cases collected from a typical deployment of the vessels described.

Since a rather dramatic and permanent decrease occurred in at least one of the major contaminants (carbon dioxide) of the submarine atmosphere in 1967 (Weybrew 1978), it was decided to divide the health data from these submarine reports into two groups, one representing the period 1963 to 1967 and one 1968 to 1973. This was done to determine if any relationship existed between the illness rate (or number of days lost from duty) and changes in the atmosphere (Table 2). The submarine data were also classified according to the conventional system of medical specialties to enable comparisons with illness rates in other areas of occupational medicine. A summary of this classification is shown in Table 3 and a detailed breakdown is presented in Tables A1–12 in the Appendix. For the statistical analysis it was assumed that the data had a Poisson distribution. The standard error of the ratio estimate was used to determine the variance and the t-test was employed to determine statistical significance (Snedecor and Cochran 1971; Armitage 1971). The statistical approach used in this study has been treated in more detail by Sheps (1966).

RESULTS

I. Comparison of illness rates between submariners and surface fleet personnel

Table 1 summarizes the total illness rate and rate of days lost from duty for each illness category of the submarine and surface populations.

Respiratory

From Table 1 it can be seen that respiratory problems, which include the classification ear, nose, and throat disease, accounted for 0.03 new cases/1000 man-days; they were responsible for the third highest rate of days lost (0.678 days/1000 man-days). Although submariners had a respiratory illness rate approximately one-quarter that of surface personnel (0.03 vs. 0.13 new cases/1000 man-days) ($P < 0.01$), the rate of days lost from duty was approximately one-half (0.8 vs. 0.14 days/1000 man-days, respectively).

Trauma

Trauma and gastrointestinal disturbances shared the position of next most common illness (0.04 new cases/1000 man-days) aboard submarines (Table 1). Trauma accounted for the highest rate of days lost from duty (0.16 days lost/1000 man-days) in the submarine population. Although the number of new cases of trauma/1000 man-days aboard the submarine was lower

TABLE 2
ILLNESS RATE AND RATE OF DAYS LOST IN SUBMARINE SERVICE

	1963–1967		1968–1973	
	Illness Rate	Rate of Days Lost	Illness Rate	Rate of Days Lost
Respiratory	0.07	0.23	0.03*	0.08*
Trauma	0.05	0.25	0.04	0.16
Gastrointestinal	0.05	0.22	0.03*	0.12*
Dermal	0.02	0.09	0.02	0.04*
Infection	0.02	0.05	0.01*	0.04
Genitourinary	0.02	0.09	0.01	0.05*
Systemic	0.01	0.11	0.01	0.06*
Cranial	0.02	0.05	0.01	0.04
Neuropsychiatric	0.004	0.03	0.01*	0.04*
Miscellaneous	0.003	0.01	0.0015	0.002*
Total	0.268	1.13	0.184*	0.63*

National Center for Health Statistics

	1963–1967	1968–1971
Neuropsychiatric (From public outpatient psychiatric services, 25–34 year age group)	0.012	0.018*

Total man-days 1963–1967 = 3,240,000; 1968–1973, 4,410,000. *Differences between two reporting periods within the submarine service and National Center for Health Statistics significant at the 5% level or better.

than that aboard surface vessels ($P < 0.01$), the rate of days lost from duty aboard the submarines was higher ($P < 0.01$).

Gastrointestinal

There was a much higher gastrointestinal illness rate aboard surface vessels ($P < 0.05$) and a higher rate of days lost from duty, compared to those for submariners.

Dermatologic

The dermatologic illness rate and rate of days lost from duty aboard submarines and surface vessels corresponded with each other closely.

Infection

Both the illness rate and the rate of days lost from duty for this cause were higher in the surface fleet population.

Genitourinary

Genitourinary disorders had an illness rate of 0.014 new cases/1000 man-days, causing a rate of days lost from duty of 0.046 days/1000 man-days (Table 1). The submariners tended to have a higher genitourinary illness rate than the surface population and nearly five times the rate of days lost from duty in this category ($P < 0.01$).

Systemic

This category included mononucleosis, viremia, rheumatoid arthritis, and cardiovascular problems, which accounted for the majority of cases. Illness in this category showed a much higher rate aboard submarines than in the surface population, 0.01 vs. 0.004 new cases/1000 man-days ($P < 0.05$), and the rate of days lost from duty in this category for the surface population was essentially 0.00.

Head

This category included disorders of the eyes, nose, teeth, and also the specific complaint of headache. Dental problems accounted for the greatest number of cases treated in this category, with headaches causing the most days lost from duty. Both total rates were higher aboard submarines ($P < 0.05$), with the rate of days lost from duty aboard surface vessels in this category essentially zero.

Neuropsychiatric

Neuropsychiatric disorders had an illness rate of 0.012 new cases/1000 man-days among submariners, resulting in a rate of days lost from duty of 0.04 days/1000 man-days (Table 2). Illness rate and rate of days lost were significantly higher than those observed in the surface population ($P < 0.05$).

Miscellaneous

Reactions to immunizations, serum sickness, medication reactions, sea-sickness, and alcohol withdrawal accounted for the disorders in this category. Total rates in the surface population were higher than those observed aboard submarines.

II. Comparison of illness rates between two reporting periods, 1963–1967 and 1968–1973, in submarine personnel

Table 2 contains a comparison of illness rates between two reporting periods, 1963–1967 and 1968–1973. Data were classified in the same manner as in Table 1, according to the format

of the standard monthly outpatient morbidity report (NavMed 6300-1). It can be seen that during 1968–1973 there was a significant decline in both the incidence of illness and the rate of days lost from duty compared to the earlier reporting period. Of the 10 categories of illnesses listed, the decrease was most pronounced in respiratory and in gastrointestinal diseases. There was also a significant decrease in the rate of days lost in genitourinary diseases. On the other hand, illness rate and rate of days lost because of neuropsychiatric diseases increased between the two reporting periods, but the same was true for neuropsychiatric cases in a comparable age group (25–34) in the general civilian population. Outpatient morbidity data for psychiatric disease for the 25–34 year age group for roughly comparable periods, 1963–1967 and 1968–1971, were obtained from the National Center of Health Statistics. Since these data were collected by physicians, they are comparable to the data collected by physicians on submarines. During the period 1963–1967, the illness rate of neuropsychiatric disorders was 0.012, and it increased significantly to 0.018 during the period 1968–1971.

Classification by medical specialties

Table 3 contains a summary of the submarine data on illness rates and days lost categorized according to the conventional medical specialties. A detailed breakdown of the 12 individual medical specialties is presented in the Appendix (Tables A1–A12). The total cases in internal medicine showed a significant decline between the two periods; the decrease in illness rate for respiratory diseases contributed to this decline. Table A1 lists the specific respiratory illnesses encountered aboard submarines. Pneumonia, upper respiratory illnesses, and acute bronchitis accounted for the greatest number of treated cases and the greatest number of days lost from duty within this category. The statistics for almost every specific illness showed improvement in the last 5-year period.

Wilken's review (1969) of 360 medical patrol reports emphasized that upper respiratory infections represented the greatest number of sick calls but usually did not result in sick days. In general, they are only listed when sick days are involved, which explains the seemingly small number of upper respiratory infections.

The incidence of cardiovascular disease is very low, five cases in the first reporting period and four in the second period, which attests to the good selection of submarine personnel. The number of sick days was 50% higher in the first period, which is probably related to the long-lasting treatment of three cases of hypertension. Not a single case of hypertension was listed during the second reporting period. Gastrointestinal diseases exhibited a major decrease in illness rate (Table A2), accounted for mainly by a spectacular decline in the incidence of gastroenteritis (Table A3). The incidence of neurological cases increased during the latter reporting period because of a more frequent occurrence of migraine headaches. However, the rate of days lost due to sickness declined (Table A4). The category of general medicine, which comprises infections, influenza, flu syndrome, and mononucleosis, showed a marked decrease in both illness rate and rate of days lost in the second reporting period (Table A5). Psychiatric disorders exhibited an increase between the two reporting periods both in illness rate and in rate of days lost from duty. These changes were caused by a higher incidence of anxiety reactions and depressions (Table A6). Of the other medical specialties, illness rate and rate of days lost decreased significantly in the category of ear, nose, and throat diseases (Table A8). The rate of days lost decreased also in the diseases of the urinary tract category. The changes in the latter category were mainly accounted for by a decrease in the incidence of ureteral calculi (Table A10). In the other medical specialties (general surgery (Table A7), eye (Table A9), orthopedics (Table A11), and dental (Table A12)), no significant changes were observed.

TABLE 3

ILLNESS RATE AND RATE OF DAYS LOST IN SUBMARINE PERSONNEL IN 885 PATROLS DURING 1963–1967 AND 1968–1973

	1963–1967					1968–1973				
	No. Cases	Illness Rate	Sick Days	Rate of Days Lost	Transfer at Sea	No. Cases	Illness Rate	Sick Days	Rate of Days Lost	Transfer at Sea
Respiratory	121	0.039	480	0.148	2	64	0.015*	215	0.049*	5
Cardiovascular	5	0.001	36	0.011	1	4	0.001	18	0.004	1
Gastrointestinal	139	0.043	462	0.143	2	90	0.020*	234	0.053*	4
Neurology	19	0.005	162	0.050	2	34	0.008	161	0.036	2
General medicine	143	0.044	554	0.171	0	97	0.0219*	382	0.086*	0
Sub-total	427	0.1318	694	0.5228	7	289	0.065	1010	0.23	12
Psychiatry	9	0.002	69	0.021	0	49	0.011*	169	0.038*	3
General surgery	97	0.030	540	0.167	2	172	0.039	563	0.128	4
Ear, nose and throat	117	0.036	296	0.091	0	58	0.013*	130	0.029*	1
Eye	23	0.007	77	0.024	1	25	0.006	44	0.010	2
Urology	55	0.017	267	0.082	0	60	0.013	193	0.043*	3
Orthopedics	132	0.041	664	0.205	1	132	0.030	619	0.140	0
Dental	21	0.006	61	0.019	0	29	0.006	44	0.010	1
Total	871	0.2668	3668	1.132	11	814	0.1846*	2772	0.6286*	26

Total man-days 1963–1967 = 3,240,000; 1968–1973 = 4,410,000. *Differences between two reporting periods statistically significant at the 5% level or better.

DISCUSSION

Differences between submarine and surface fleet personnel

It is apparent that the illness rates aboard submarines and surface vessels are both relatively low. The fact that the total illness rate was lower aboard submarines is not surprising because submarine crews undergo a more intensive physical and dental screening program and, therefore. should be a healthier population at the beginning of deployment. Also, the crew breakdown (submarine: E-2, 0.02: E-3, 0.04: E-4, 0.25; E-5, 0.31; E-6 and above, 0.38; surface: E-2, 0.20: E-3. 0.23: E-4, 0.24: E-5, 0.15: E-6 and above, 0.18) shows that the typical crew of a *Polaris* submarine is more senior, with only 6% of the total crew in the E-2 or E-3 level compared to 43% of the crew of a typical surface vessel (Gunderson, personal communication). Gunderson. Rahe. and Arthur (1970) have presented data that suggest that the lower rated men tend to have a higher illness rate. On the other hand, personnel with higher pay grades usually have longer in-service time, are older, and are more disease-prone. A few additional differences that exist between the two populations should be considered: 1) the physician-to-population ratio is lower aboard submarines; 2) submariners are not exposed to natural variations in sunlight; 3) quarters aboard submarines are much closer; 4) two-month periods of isolation in a sealed environment are required for the crews of nuclear-powered submarines, and 5) the submarine atmosphere contains contaminants, such as CO, CO_2, aerosols. and hydrocarbons, in low concentrations.

As noted above, illness rates were higher among the surface population in all categories, with four exceptions: genitourinary. systemic, head, and neuropsychiatric. Genitourinary problems were more common in submariners and consisted primarily of the ureteral calculi discussed above. The increased level of CO_2 in the submarine atmosphere may have contributed to the higher incidence of ureteral calculi in submarine personnel; evidence obtained in animal experiments shows increased kidney calcification during prolonged exposure to 1% CO_2 (Schaefer, Pasquale. Messier, and Niemoeller 1979b). Those illnesses under the systemic heading (including infectious mononucleosis) were much more common in submariners; the reason for this remains obscure. Illnesses involving the head were also more frequent in submariners: dental problems and headaches were the cause of most cases treated in this category. These headaches were probably not related to the elevated carbon dioxide concentrations: carbon dioxide concentrations in the range observed (usually less than 1%) rarely cause headaches severe enough to cause a man to leave duty. If there were a direct relationship. the incidence of headaches (Table A4) should have been higher in the first reporting period when the carbon dioxide concentration was higher. The incidence rates of neuropsychiatric illnesses on submarines with 9 cases/million man-days and surface fleet with 6 cases/million man-days are low compared with those of the 25–34 year age group in the general population, which had a rate of 18 cases/million man-days in 1971, based on data from public outpatient psychiatric services. The higher incidence of headaches and neuropsychiatric disorders in submarine personnel may be related to a greater overall stress effect imposed by two months of isolation in the submarine. However, at present there is no data to substantiate this.

Comparison of illness rates between two reporting periods (1963–1967 and 1968–1973) in submarine personnel

The total illness rate (new cases/1000 man-days) declined significantly (−33%) in the second reporting period compared to the first one. The following disease categories (classified accord-

ing to medical specialties) showed a decrease in incidence: 1) respiratory; 2) ear, nose, and throat; 3) gastrointestinal; 4) cardiovascular; 5) urology; and 6) general medicine (comprising among others infections, influenza, mononucleosis). Not affected were the number of cases in general surgery, orthopedics, dental, or eye. Neurology and psychiatry were the only disease categories in which an increased incidence occurred.

The way in which these three different groups of diseases were influenced suggests the role of improved atmosphere control, a development that took place during the 10-year period in which these medical reports were made. A reduction in air pollution is known to reduce the incidence of respiratory diseases but is unlikely to have changed the incidence of surgical, orthopedic, and dental cases. However, other factors must also be considered that might have influenced illness rates.

Factors which could have influenced illness rates

1) Selection of healthier sailors. A change in the selection program of naval personnel which stipulated more stringent requirements during the second reporting period (1968–1973) would have resulted in the selection of healthier sailors and consequently lower illness rates, but there were no changes in the selection criteria or procedures during this period.

2) Possible influence of a different reporting system of medical cases. It could be argued that the reduction in illness rate during the period 1968–1973 may have been the result of a different reporting system. If this had been the case, all categories or morbidity would have shown a decrease, which was not the case. The incidence rate in the categories dermal and systemic diseases stayed the same and that of neuropsychiatric disease increased. Moreover, the reporting of medical cases was limited to those that resulted in sick days, and is based on a very simple criterion, which was not changed throughout the whole reporting period. The major decrease in incidence of illness occurred in respiratory, gastrointestinal, and genitoureteral disease, involving those physiological systems for which pronounced CO_2 effects have been found in patrol studies and in laboratory experiments in men and animals.

3) Effect of a general downward trend in illness rates. The observed decrease in incidence of illness might possibly reflect a general downward trend in illness rate in the disease categories in the general population; however, the opposite occurred. The days of bed disability due to respiratory and gastrointestinal diseases of the 17–44 year age group (male) reported by the National Health Survey increased between these two periods for both respiratory and gastrointestinal disease, from 3.44 man-days/1000 men to 4.5 and from 0.35 to 0.45, respectively. The incidence rate of respiratory diseases increased from 2.38/1000 man-days to 2.76/1000 man-days, while that of gastrointestinal disease stayed the same. Although the NHS interview data are not directly comparable to the data collected on submarines, the trends indicated are useful.

It can be concluded that the reduced incidence rates in the respiratory and gastrointestinal categories in the submarine population in the second study period are not explainable by a similar and concurrent decrease in these diseases in the general population.

Enterline and Stewart (1960) published data on estimated morbidity in the civilian labor force and the armed services for the period 1947 to 1959. Based on the monthly reports of the average daily proportion of total manpower unavailable for duty during each month because of illness, a slight but regular decline in the prevalence of illness occurred in the Navy and the

other Armed Forces. The question must therefore be raised whether this general decline continued and was reflected in the observed decrease between the two reporting periods. For respiratory disease, which represents a major source of the decline of illness rates, a year-by-year comparison was made (Fig. 1b) which showed not a gradual decline but an abrupt change corresponding with the decline in the atmospheric pollutant CO_2 (Fig. 1a). This finding represents evidence speaking against a general gradual decline of illness rates and indicates that the reduction in air pollutants plays a major role in the decrease in the rate of respiratory disease.

4) *Possible changes in pattern of respiratory diseases.* The pattern of respiratory diseases during patrol is of course affected by the rate at which the crew contracted acute respiratory diseases during the 3-week refit period before patrol that involved mixing with the local community at the SSBN base either in Scotland or Spain. Sphar and Evans (1976) carried out detailed seroepidemiological studies of four different *Polaris* submarine crews during the period 1970–1973 and demonstrated that respiratory infections, particularly upper respiratory infections, were principally confined to the refit period and involved 43 and 26.6 percent of two crews studied. Incidence of upper respiratory infections showed a short secondary peak

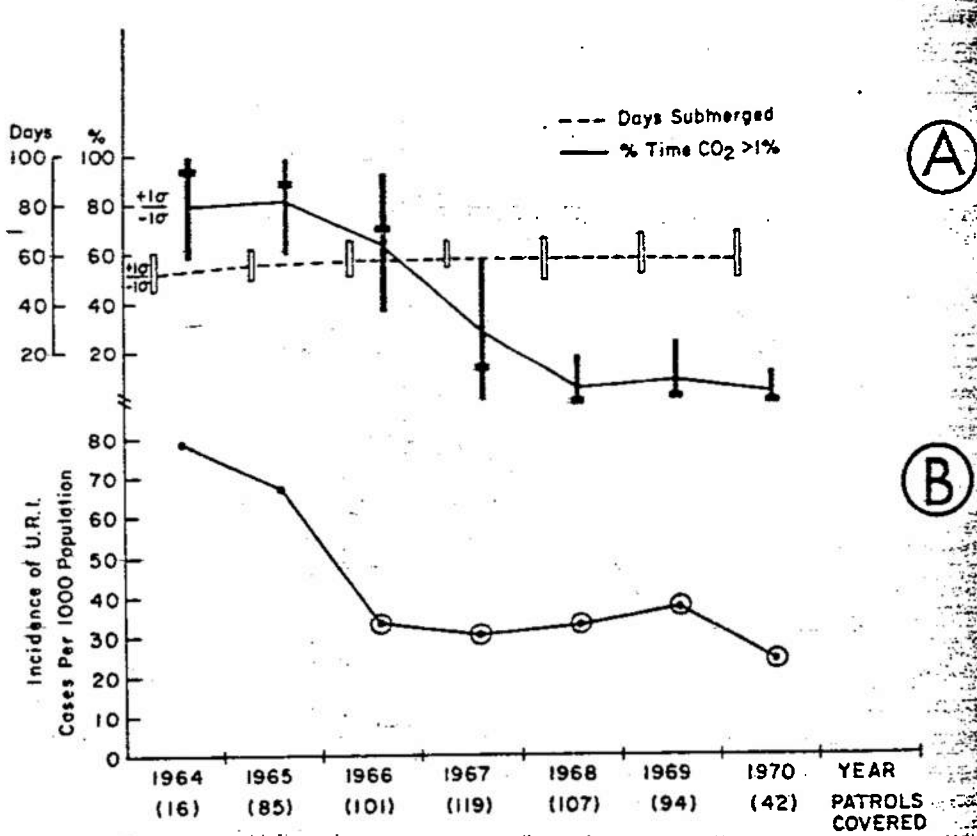

Fig. 1. *A*, Summary of average ambient CO_2 levels on 546 Fleet Ballistic Missiles (FBM) submarine patrols between 1964 and 1970; *B*, incidence of upper respiratory infection cases per 1000 population observed on 546 Fleet Ballistic Missile (FBM) submarine patrols between 1964 and 1970. ⊙ = Incidence significantly different from data obtained in 1964.

during the second week of patrol in one crew and decreased during the rest of patrol. This pattern of mild preparatory refit period respiratory illness, which dies out during the patrol, is in agreement with the earlier findings of Watkins (1970), who summarized the results of studies of 360 patrols between 1963–1967 made by the staff of the Naval Biological Laboratory of the University of California. These reports demonstrated that the pattern of respiratory disease did not change during the 1963–1973 period covered by this paper. These authors also provided an explanation for the low incidence of respiratory disease during patrol.

There are two reports of a different pattern of respiratory disease during patrol; in both cases there was a mid-patrol outbreak between the third and fourth weeks at sea, respectively (Sawyer and Sommerville 1966; Watkin 1970). Two different explanations have been offered for this phenomenon: a long incubation time and low immunity level (Sawyer and Sommerville 1966) and the activation of an unidentified virus in the crew (Watkins 1970).

5) Effect of changed work-rest schedules and desynchronization of circadian cycles on resistance to disease. Another explanation should be discussed. Ever since Halberg (1962) reported about the influence of circadian cycles on susceptibility to i.p. injection of *E. coli* endotoxin—that the same amount of endotoxin kills 80% of mice at one time and 20% at another—the role of circadian cycles in resistance to diseases has been followed up and has been clearly established (Smolensky, Halberg, and Sargent 1975). It is also a matter of general experience that desynchronization of internal circadian cycles from environmental cycles (time givers) occurring after jet flights across several time zones causes increased susceptibility to colds and respiratory infections. Observations of circadian cycles during patrols demonstrated internal desynchronization of cycles of respiratory frequency, heart rate, and body temperature and the development of 18-h cycles in the functions reflecting the 18-h watch-schedule (6 h on watch followed by 12 h off watch) (Schaefer, Kerr, Buss, and Hauss 1979a). The desynchronization takes weeks to develop and could be the cause of a reduced resistance which might in turn lead to an outbreak of dormant respiratory infection. The 6 h on, 12 h off watch schedule produces a shift in meal timing that has been shown to cause internal desynchronization of hormones, which control metabolic functions (Lakatua, Hauss, Swoyer, Halberg, Thompson, and Sackett 1974). Isolation and reduction of physical activity, two factors that play an important role in submarine patrols, have also been shown to cause desynchronization of circadian cycles (Schaefer, Clegg, Carey, Dougherty, and Weybrew 1967; Schaefer and Clegg 1966). Taken together with the effects of desynchronization of circadian cycles caused by nutrition and sleep-wakefulness, the disturbance of circadian cycles has to be viewed as an important factor affecting the well being of personnel and probably their resistance to disease. However, the factors responsible for the desynchronization of cycles have not changed during the 10-year period during which the health data on submarine personnel were collected. It is therefore unlikely that they were involved in the reduction in illness rate observed during this period in six disease categories.

Increase in illness rate of neuropsychiatric disorders

To explain the observed increase in neuropsychiatric disorders, one would have to know whether the conditions during patrol changed to produce greater stress. If this were true, one would expect to see a higher incidence of neuropsychiatric disorders during patrol compared to the period prior to patrol. In a study of the time course of morbidity patterns of 554 SSBN missions completed between 1964 and 1970, Weybrew, Bryan, and Noddin (1978) found that the incidence rates of both neuropsychiatric disorders and headaches stayed the same during

the period prior to the patrol (which includes the refit period) and the patrol. This means that neither the experience of isolation nor prolonged exposure to contaminants of the submarine atmosphere had an effect on the rate of neuropsychiatric disease.

To bring these findings into perspective, a comparison was made with the illness rate of neuropsychiatric disorders for the 25–34 year age group in the general population, which turned out to be twice as high as that of submarine personnel. These data were obtained from outpatient psychiatric services and were made available by the National Center for Health Statistics (Kleinman, personal communication). Since the outpatients were seen by doctors, these data are generally comparable with the submarine data. They represent the only pertinent information that could be obtained for a comparison. An increase from 12 to 18 cases/million man-days was observed in the general population during the two comparable periods 1963–1967 and 1968–1971. It is most likely that the observed rise in incidence rate of neuropsychiatric illness in the general population is reflected in the increase of this condition in the submarine fleet. This notion would be better supported if the incidence rate of neuropsychiatric disorders in the surface fleet had also increased between 1963 and 1973. However, outpatient morbidity data of the surface fleet during these periods 1963–1967 and 1968–1974 were not available at the Naval Data Science Center, Bethesda, Maryland.

6) The effect of decreased contaminants in the submarine atmosphere on illness rate. During the period from 1965–1968, the old CO_2 scrubber (monoethanol-amine scrubbers), which had a capacity of 250 cubic ft, were replaced by larger, more efficient units of 400 cubic ft capacity. New regulations were introduced that stipulated that the two CO_2 scrubbers were to be run together and often simultaneously. This resulted in a marked decrease in the average ambient CO_2 level in submarines.

CO_2 levels recorded during individual submarine patrol studies are listed in Table 4. These data may not be representative for the whole fleet; however, they give some indication of the improvement of the atmospheric control achieved during the period in which the medical patrol reports were made. Data indicate a 33% fall in CO_2 levels.

Figure 1a presents a summary of CO_2 levels from 546 submarine patrols between 1964 and 1970 (Weybrew 1978). It can be seen that the percent of patrol time during which the CO_2 level was above 1% declined sharply in 1968, although the duration of patrols increased slightly. On the basis of these atmospheric data, it was decided to compare the periods 1963–1967 and 1968–1973.

Other measures to improve the atmosphere control in submarines consisted of more frequent replacement of 1) carbon beds in the filter systems and 2) ion exchange resins in the discharge side of the scrubbers. Moreover, more efficient catalytic burners were introduced during this period. With the improvement of the atmosphere control system, other contaminants such as CO, hydrocarbons and ammonia, Freon 11 and Freon 12 also decreased (Carhart 1977 personal communication). Carbon monoxide showed a fall of approximately 66% (Table 5). Since multiple factors were involved, it is not possible to establish a single cause-effect relationship between the decline of one atmospheric pollutant and the decrease in illness incidence. However, the relative importance of individual factors can be explored. Several criteria can be used: 1) Were the contaminants of the submarine air present in concentrations above or below a threshold level known to exert biological effects? 2) Is it possible that contaminants below threshold level interacted with other contaminants to produce biological effects? As will be shown later, CO_2 levels in the range of 1.2–0.8%, observed in the submarine atmosphere during the period reported, caused significant reactions, while ambient CO concentrations in the range of 40–15 ppm had only minimal effects on O_2 transport. Hydrocar-

TABLE 4
DECLINE IN CO_2 AND CO CONCENTRATIONS IN SUBMARINE ATMOSPHERE BETWEEN 1961 AND 1973

Average Ambient Level during Patrol	Year Observed	Author
	Carbon Monoxide	
44 ppm	1961	Schulte 1961
15–20 ppm	1969	Wilson and Schaefer 1979
8–10 ppm	1972	Lightfoot 1972
7–8 ppm	1977	Bondi 1978
	Carbon Dioxide	
1.2%	1966/67	Hughes 1969
0.97%	1967	Schwartz 1969
1%	1967	Piebenga and Shiller 1968
0.90%	1967	Gude and Schaefer 1969
0.79%	1968	
0.90%		
0.90%	1969	Gortner et al. 1971
0.85%	1969	Peck 1971
0.85%	1971	Braithwaite 1972

TABLE 5
CHANGES IN SMOKING HABITS OF ENLISTED CANDIDATES FOR SUBMARINE SERVICE

	1967 (n = 347)		Jan 14, 1977 (n = 225)	
Non-Smokers	94	27%	89	40%
Occasional Smoker (Parties, when offered)	24	7%	19	8%
Light Smokers (1/4 pkg. cigarettes or 1 pipeful or 1 cigar a day)	52	15%	18	8%
Moderate Smoker (1–1¼ pkg. or 10 pipefuls or 8 cigars/day)	160	46%	87	39%
Heavy Smoker (2 + pkgs cigarettes, 12 + pipefuls or 9 + cigars/day)	17	5%	12	5%

With df = 4, P of $\chi^2 < 0.01$; data were collected anonymously, diminishing motivation to lie.

bons in higher concentrations are known to cause changes in serum enzyme levels, such as glutamic oxalacetic transaminase (SGOT), serum glutamic pyruvic transaminase (SGPT), and serum lactic dehydrogenase (LDH), which indicate cell changes. In a patrol study by Larkin (1967), these serum enzyme levels were unchanged.

The role of increased CO_2 levels in the submarine atmosphere (patrol studies)

The threshold limit value for 90-day continuous exposure to CO_2 in submarines was established at 0.5% CO_2 (Nuclear Powered Submarine Atmosphere Control Manual). However, during the first reporting period from 1963–1967, the average CO_2 concentration was usually above 1% CO_2 (Fig. 1a). During the last 10 years, studies have been carried out on patrols to determine whether prolonged exposure to the CO_2 and CO levels on submarines has an effect on physiological functions. The results have been summarized in three recent reports (Schaefer 1979; Messier, Heyder, Braithwaite, McCluggage, Peck, and Schaefer 1979; and Wilson and Schaefer 1979).

It has been established that exposure to 0.8–1% CO_2 on submarines has pronounced effects on respiration, resulting in an increase in respiratory minute volume and physiological dead space. Acid-base balance studies showed cyclic alterations between metabolic and respiratory acidosis at 20-day intervals, indicated by changes in blood pH and blood bicarbonate and P_{CO_2}. These cycles in acid-base balance appear to be related to cycles of similar length in calcium excretion. It has been suggested that the observed cycles in acid-base balance and calcium excretion are related to CO_2 uptake and release in the bones, which require time periods fitting the length of the cycles (Schaefer 1979). Recent animal studies, in which guinea pigs were exposed to 1% CO_2 for 8 weeks, have provided confirmatory evidence for this hypothesis (Schaefer et al. 1979a). In addition, gastric acidity increased during patrol, returning to normal after four weeks on air.

The results of these physiological studies during 23 patrols demonstrated hypercapnic, physiological stresses on the respiratory system, on acid-base balance, and calcium metabolism, which were confirmed in British studies on acid-base balance (Pengree 1977) and calcium metabolism (Gray, Lambert, and Morris 1969; Gray, Morris, and Brooks 1973). Davies (1973) discusses the pathophysiological and metabolic costs of a 60-day patrol, and focuses on the effects of chronic hypercapnia. He considers as possible health hazards: CO_2-induced nephrocalcinosis, possible hypertension of renal origin, chronic lung diseases, and hemopoietic abnormalities. Davies (1973) points out that the nuclear submarine program is not yet old enough for any true incidence of disease to have become apparent.

Laboratory studies of chronic hypercapnia

Findings obtained during patrol studies are in close agreement with laboratory experiments in which human subjects were exposed to 1.5% CO_2 for 42 days (Schaefer, Hastings, Carey, and Nichols 1963a; Schaefer, Nichols, and Carey 1963b; Schaefer, Nichols, and Carey 1964). Recent and carefully controlled studies in animals demonstrated that prolonged exposure of guinea pigs to 1% CO_2 causes kidney calcification and lung changes. It was found that under these conditions calcium moves out of the bone in connection with the CO_2 uptake of bones. Calcium is taken up in soft tissues, resulting in increased calcium content of the kidneys and a higher incidence of kidney calcification (Schaefer 1979a).

Prolonged exposure of guinea pigs to 1% CO_2 caused ultrastructural changes of the lung that were still present after two and four weeks' recovery on air following four weeks of exposure

to 1% CO_2 (Douglas, Schaefer, Messier, and Pasquale 1979). The most recent animal experiments with guinea pigs exposed to 0.5% CO_2 for 8 weeks demonstrate that under these conditions kidney calcification does occur. Moreover, the ultrastructural changes of the lungs observed in guinea pigs after 4 weeks' exposure to 1% CO_2 were not present after this same exposure to 0.5% CO_2 (Schaefer, Messier, Pasquale, and Douglas 1979). These findings in animal experiments indicate that at 0.5% CO_2 a threshold is being approached for physiological effects of chronic hypercapnia.

It is difficult to extrapolate from animal studies to humans, but in view of these findings showing the disappearance of ultrastructural changes of the lungs and a longer time for kidney calcification to develop when the ambient CO_2 level is decreased from 1% CO_2 to 0.5% CO_2, it is to be expected that a 30% reduction of ambient CO_2 levels in submarine air from 1.2%–0.8% would result in fewer adverse CO_2 effects on lung and kidney functions.

Interaction of CO_2 and other factors

Other factors of the submarine environment may interact with CO_2 effects. If the vitamin D deficiency (due to artificial lighting) found in the British patrol studies (Davies and Morris 1979) is controlled by supplying vitamin D and installing lamps covering the ultraviolet range, the potential for CO_2-induced renal retention of calcium has to be investigated.

Moreover, exposure to increased levels of CO in the submarine air (15–20 ppm) was found to cause an increase in red cells, hematocrit, and hemoglobin in both smokers and nonsmokers. These changes were considered a response to the slight hypoxic effects produced by CO, and they returned to control values during the recovery period (Wilson and Schaefer 1979). In a recent patrol study (Bondi 1978), a CO level of 7–8 ppm was observed, which is similar to the 8–10 ppm levels determined by Lightfoot in British submarines in 1972.

In addition to the improvement of atmospheric control on submarines, changes in the smoking habits of submarine personnel may have contributed to the decrease in carbon monoxide concentrations in the submarine atmosphere. Weybrew (1974) compared the smoking habits of enlisted candidates for submarines in 1967 and again in 1977 and found a 13% increase in nonsmokers, a 7% decrease in light smokers, and a 6% decrease in moderate smokers (Table 5). If we assume that a similar decrease of 13% in the number of light and moderate smokers took place between the two reporting periods, the incidence of respiratory problems may also have been reduced by this factor.

Taking all these reported findings into account, one has to assume that the physiological stresses on the respiratory and the gastrointestinal systems produced by prolonged exposure to increased CO_2 levels may have contributed to the rate of illness related to these systems. Evidence showing a decrease in the illness rate associated with a decrease in CO_2 levels supports this notion. Advances in atmosphere control led to a significant and permanent decrease in the carbon dioxide concentration aboard *Polaris* submarines during 1967 (Weybrew et al. 1978), which is shown in Fig. 1a. The illness rate of upper respiratory infection (URI) measured during the same patrols is plotted in Fig. 1b. The decline in illness rate of URI during the period 1963–1967 corresponds with the stepwise decrease of CO_2 concentration in the submarine atmosphere during this period. From 1968 on, the CO_2 concentration remained stable and so did the URI illness rate. These findings support the hypothesis that the reduction in ambient CO_2 levels influenced the illness rate of respiratory disorders as URI. Moreover, a decline in the incidence of gastroenteritis was also observed after a decrease in CO_2 levels. The illness rate of ureteral calculi aboard the submarines during the earlier reporting period, when the carbon dioxide concentration was higher, was 0.007 new cases/1000 man-days; the

illness rate for ureteral calculi aboard submarines is 0.005 new cases/1000 man-days, which is exactly the same as that for the general population (Health Interview Survey, 1975).

Although it is not possible to prove a direct causal relationship between improvement of atmospheric control in submarines and decrease in disease, the association is strongly suggested. If the illness rate observed during the 1963–1967 period is applied to the second reporting period, 1968–1973, an additional 2211 working days would have been lost due to sickness, which is a very small percentage of the total number of man-days involved (7,650,000).

A summary of health factors in the current submarine environment is presented in Table 6. The health factors are classified into two groups 1) environmental contaminants and 2) modes of life style and living conditions that are known to affect health. To evaluate the relative importance of these health factors, three tolerance levels were chosen by extending a previously published concept of triple tolerance limits, based on chronic CO_2 studies (Schaefer 1961), that can be applied generally to grade effects of other contaminants and factors influencing health. The three levels (Table 6) are: 1) levels producing performance deterioration, alterations in basic physiological functions, indicated by changes of pulse rate, blood pressure, metabolism, body weight, and, finally, pathological changes; 2) the level at which performance and basic physiological functions are not significantly affected (under these conditions, however, slow adaptive processes are observed in various physiological functions that might induce pathophysiological changes during greatly prolonged exposure); and 3) the level at which significant physiological, psychological, or adaptive changes probably do not occur. Subtle effects may occur that are difficult to measure. These three ranges have been delineated for ambient CO_2 by the concentration of 3% CO_2 and 0.5% CO_2, and for ambient CO by 100 ppm and 7 ppm. Above 3% CO_2 and 100 ppm CO, performance changes have been observed. Carbon dioxide at the 0.5 level appears to be a threshold concentration which causes only subtle changes in animals after prolonged exposure for 8 weeks. It is technically feasible to maintain 0.5% CO_2 on submarines without too great an expenditure. Seven ppm have been found to be the average level of ambient CO during a patrol (Bondi, Very, and Schaefer 1978), which is below the 8-h limit of 8.7 ppm for ambient air. This CO value protects against the occurrence of 2% HbCO in the non-smoking public (Environmental Protection Agency Standard 1971). The cross-hatched area on the left (Table 6) indicates that ambient levels of 0.8% CO_2 (frequently measured in submarines) cause effects belonging in the adaptive zone (Level II). They involve adaptive changes in respiration, acid-base balance, and calcium metabolism (Schaefer 1979). As far as CO is concerned, only minimal effects (Level III) can be detected at an ambient level of 7 ppm. Turning to the life style columns (Table 6), it can be seen that four factors represent well-known cardiovascular risk factors—smoking, high caloric intake, physical inactivity, and high coffee intake. During patrol, smokers had an average HbCO content of 3.79% upon awaking and 6.45% upon retiring. This level of HbCO has an impairing effect on O_2 transport. High caloric intake during patrol, amounting to 3400–3600 kcal/person (Messier et al. 1979) together with the semi-sedentary life style imposed on the crews by the confined submarine environment, is the most likely cause of increased blood cholesterol concentrations during submarine patrols (Campbell and Rahe 1974; Shivertaker 1974). A positive correlation between length of submarine duty and blood cholesterol levels was reported by Tappan, Jacey, Heyder, and Harvey (1979). Physical inactivity has also been shown to cause desynchronizations similar to those observed in jet lag and could therefore contribute to fatigue (Schaefer and Clegg 1966). Heavy coffee drinking has been found to double the risk for myocardial infarction (Jick, Miettinen, Neff, Shapiro, Heinonen, and Slone 1973). Gilbert (1976) suspects that an intake of 8.5 mg/kg of caffeine is critical for coffee addiction and health

TABLE 6

HEALTH FACTORS IN THE SUBMARINE ENVIRONMENT

Tolerance Levels	Environmental Contaminants			Life Style Cardiovascular Risk Factors				Circadian Cycle Disturbance
Effects on Performance and Physiological Functions	CO_2	CO	Others (Hydrocarbons, Aerosols, Etc.)	1 Smoking	2 High Calorie Intake	3 Physical Inactivity	4 High Coffee Intake	(18-H Day-Night Cycle)
Level I Performance Deterioration, Physiological Changes	3%	100 ppm						
Level II No Changes in Performance and Basic Phys. Functions								
Adaptive Processes Long-range Effects	.5%	7 ppm		Increased HbCO, Decreased O_2 Transport	Increased Cholesterol, Fat	Desynchronosis	Hypertension	Desynchronosis
Level III Effects: Subtle, Difficult to Measure	0	0						

Shaded area indicates, in a semi-quantitative way, processes and long-range effects produced by environmental and life style factors in the current submarine environment.

consequences. This means that a 70-kg man need only drink four to five 8-ounce (250 cc) cups of standard brewed coffee (Henry 1978). The 18-h day (6 h on-12 h off watch schedule) commonly practiced on submarines has been found to cause 18-h cycles of pulse rates and body temperature and desynchronization of cycles of physiological functions (Schaefer et al. 1979a).

Evaluation of neural and muscular tests in Russian laboratory studies demonstrated that the 18-h day was the most detrimental to routine (Andrezheyuk 1968) causing somnolence, restlessness, and emotional tenseness with impaired coordination (Dushkov and Kosmolinskii 1968).

The shaded areas in the life style columns (Table 6) are made larger than those of the CO_2 column on the left to indicate that adverse effects on health caused by the listed life style factors are considered of greater importance than those of the current environmental contaminant levels. Possible approaches to improve health on submarines further are listed in Table 7, comparing costs with potential health benefits. It is concluded that further environmental improvements, on either a modest or a major scale, can only bring slight health benefits and therefore represent investments with diminishing returns. However, major health benefits can be achieved by improvements of different aspects of the submariner's life style. Measures in this area cost very little, but they require individual cooperation and motivation.

TABLE 7
POSSIBLE APPROACHES TO IMPROVED HEALTH

Measures	Cost, $	Degree of Potential Health Benefit
Modest environmental improvement* (CO_2 0.8–0.5%, CO < 7 ppm)	Moderate	Slight
Major environmental improvement* (CO_2 0.1%, CO, 1 ppm)	Very high	Slight
Improvement of lifestyle	Low	Substantial
Smoking prevention		
Diet		
Exercise		
Reduced coffee consumption		
24-H day-night cycles*		

* = Command prerogative; other goals require individual cooperation and motivation.

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Tansey, W. A., J. M. Wilson, K. E. Schaefer. 1979. Analyse des comptes-rendus medicaux de 10 ans de voyages des sous-marins du type "Polaris". Undersea Biomed. Res. Sub. Suppl.: S217–S246.—Nous analysons les comptes-rendus médicaux de 885 missions de sous-marins du type "Polaris". Les rapports, préparés par les médecins du bord, rendent compte de 7.650.000 hommes/jour entre 1963 et 1973. Les informations sont comparés à celles du personnel du surface (1.215.918 hommes/jour) pour une période continue de 7–8 mois, 1973. Chez le personnel de surface est observée une incidence plus grande de troubles respiratoires, gastro-intestinaux, cutanes, infectieux que chez les sous-mariniers; en revanche, ceux-là ont signalé moins de maladies génito-urinaires, systémiques (infections et mononucléose ci-inclus), craniennes, et neuropsychiatriques. A cause du contrôle atmosphérique sensiblement amélioré, paraît-il, les concentrations des contaminants atmosphériques les plus importants (CO, CO_2) sont diminuées entre 1965 et 1967 et surtout en 1967. Pour étudier la relation entre la morbidité (ou l'absentéisme) et les modifications de l'atmosphère à l'intérieur des sous-marins, nous avons comparés la statistique de la période 1963–67 à celle de la période 1968–73. Une diminution significative (−33%) de l'incidence de cas (cas neufs/1.000 hommes/jour) dans la seconde période a été constatée. L'incidence des classifications suivantes est diminuée: respiratoire, otorhinolaryngologique, gastro-intestinaux, cardiovasculaire, urologique, et général (qui comprend les infections, la grippe, et la mononucléose). Aucun effet sur l'incidence des cas chirurgicaux, orthopédiques, dentaux, ni ophthalmologiques n'est observée.

Appendix

TABLE A1
RESPIRATORY DISEASE

Diagnosis	1963–1967 Cases	1963–1967 Days	1968–1973 Cases	1968–1973 Days	Total, 1963–1973 Cases	Total, 1963–1973 Days
Pneumonia	52	281	28	105	80	386
Upper respiratory infection	30	67	13	20	43	87
Acute bronchitis	26	73	10	34	36	107
Pneumothorax	7	39	4	30	11	69
Pleurisy	3	12	3	16	6	28
Pleurodynia	2	4	2	3	4	7
Asthma	1	4	2	2	3	6
Asthmatic bronchitis			1	4	1	4
Lung infiltrates			1	1	1	1
Total	121	480	64	215	185	695
Transfer at Sea	2		5		7	

TABLE A2
CARDIOVASCULAR DISEASE

Diagnosis	1963–1967 Cases	1963–1967 Days	1968–1973 Cases	1968–1973 Days	Total, 1963–1973 Cases	Total, 1963–1973 Days
Hypertension (benign, essential)	3	33			3	33
Chest pain	1	2	1	6	2	8
Paroxysmal supraventricular tachycardia	1	1	1	1	2	2
Pericarditis			1	7	1	7
Arrhythmia			1	4	1	4
Total	5	36	4	18	9	54
Transfer at Sea	1		1		2	
Death	1					

TABLE A3
GASTROINTESTINAL DISEASE

Diagnosis	1963–1967 Cases	1963–1967 Days	1968–1973 Cases	1968–1973 Days	Total, 1963–1973 Cases	Total, 1963–1973 Days
Gastroenteritis	92	155	42	57	134	212
Gastroenteritis (staphylococcal)	1	7	20	17	21	24
Gastritis	17	24			17	24
Hepatitis (infectious)	7	187	7	90	14	277
Abdominal pain	9	30			9	30
Enteritis (diarrhea)	4	4	4	9	8	13
Cholecystitis	4	40	4	29	8	69
Gastroduodenitis	1	5	3	5	4	10
Mesenteric adenitis	2	3			2	3
Pancreatitis	1	5	1	5	2	10
Regional enteritis	1	2	1	2	2	4
Neoplasm (?) esophageal			1	2	1	2
Chemical hepatitis			1	5	1	5
Colonic colic			1	2	1	2
Nausea and vomiting			1	1	1	1
Diverticulitis			1	4	1	4
Constipation			1	3	1	3
Gastroenteritis with hemorrhage			1	3	1	3
Amoebic dysentery			1		1	
Total	139	462	90	234	229	696
Transfer at Sea	2		4		6	

TABLE A4
NEUROLOGIC DISEASES

Diagnosis	1963–1967 Cases	1963–1967 Days	1968–1973 Cases	1968–1973 Days	Total, 1963–1973 Cases	Total, 1963–1973 Days
Headache	8	17	10	43	18	60
Concussion	5	51	4	6	9	57
Migraine headache			8	59	8	59
Neuralgia			2	4	2	4
Bell's palsy			2	5	2	5
Syncope	2	2			2	2
Psychophysiologic musculo-skeletal reaction			1	23	1	23
Progressive paresthesia - arm	1	69			1	69
Post-traumatic epilepsy			1	7	1	7
Thoracic-lumbar spinal nerve neuritis			1	4	1	4
Somnolence			1	3	1	3
Sciatica			1	2	1	2
Observation for cerebral hemorrhage	1	2			1	2
Grand mal epilepsy			1	2	1	2
Myalgia			1	2	1	2
Seizure (etiology unknown)	1	1			1	1
Meningococcemia			1	1	1	1
Intermittent cerebrovascular occlusion	1	20			1	20
Total	19	162	34	161	53	323
Transfer at Sea	2		2		4	
Deaths	2		1		3	

TABLE A5
General Medical Diseases

Diagnosis	1963–1967 Cases	1963–1967 Days	1968–1973 Cases	1968–1973 Days	Total, 1963–1973 Cases	Total, 1963–1973 Days
Influenza and flu syndrome	74	160	60	170	134	330
Mononucleosis	18	162	13	160	31	322
Viremia	6	29	7	15	13	44
Urticaria	5	14	4	6	9	20
Fever of unknown origin	4	5	3	11	7	16
Diabetes mellitus	2	6	3	9	5	15
Reaction to immunization	4	7	2	2	6	9
Serum sickness	4	22			4	22
Angioneurotic edema	2	6	1	1	3	7
Dermatophytosis	3	18			3	18
Gout	1	7	1	3	2	10
Electrocution	1	1	1	1	2	2
Drug reaction			2	4	2	4
Ankle edema	2	2			2	2
Erysipelas	2	4			2	4
Medical observation	1	22			1	22
Rheumatoid arthritis	1	27			1	27
Post-streptococcal arthritis	1	6			1	6
Osteoarthritis	1	7			1	7
Scarlet fever	1	5			1	5
Asymptomatic albuminuria	1	2			1	2
Pectoralis myalgia	1	1			1	1
Avitaminosis C	1	1			1	1
Vitamin B deficiency	1	7			1	7
Delirium tremens (alcohol)	1	9			1	9
Physical exhaustion	1	1			1	1
Skin infection (unspecified)	1	7			1	7
Impetigo	1	3			1	3
Subacute eczema	1	6			1	6
Erythema multiforme	1	7			1	7
Total	143	554	97	382	240	936

TABLE A6
Psychiatric Syndromes

Diagnosis	1963–1967 Cases	1963–1967 Sick Days	1968–1973 Cases	1968–1973 Sick Days	Total, 1963–1973 Cases	Total, 1963–1973 Sick Days
Anxiety reaction	3	9	22	26	25	35
Depression, neurotic	2	3	11	20	13	23
Situational reaction, adult			4	18	4	18
Schizophrenia, paranoid	1	30	2	58	3	88
Suicide gesture			3	23	3	23
Insomnia			1	8	1	8
Depression, psychotic			1	1	1	1
Paranoid reaction			1	7	1	7
Aggressive reaction			1	2	1	2
Claustrophobia			1	4	1	4
Maladjustment			1	1	1	1
Dyssocial personality			1	1	1	1
Transient stress reaction	1	1			1	1
Psychoneurosis	1	4			1	4
Psychosis, unspecified	1	22			1	22
Total	9	69	49	169	58	238
Transfer at Sea			3		3	
Death	1				1	

TABLE A7
General Surgery

Diagnosis	1963–1967 Cases	1963–1967 Sick Days	1968–1973 Cases	1968–1973 Sick Days	Total, 1963–1973 Cases	Total, 1963–1973 Sick Days
Appendicitis	31	217	39	252	70	469
Pionidal abscess	19	19	26	29	45	107
Burns, 2 and 3 degree	11	68	12	77	23	145
Abscess	2	4	17	34	19	38
Ingrown nail			14	4	14	4
Furuncle and carbuncle	1	2	12	11	13	13
Thrombophlebitis	4	29	8	34	12	63
Perirectal abscess	3	15	8	15	11	30
Wound infection			6	9	6	9
Hemorrhoid, thrombosed			6	3	6	3
Hemorrhoids	5	12			5	12
Laceration	9	28	4	15	13	43
Abdominal pain			4	7	4	7
Laceration, infected	2	2	2	6	4	8
Hernia, inguinal	2	11	1	14	3	25
Small bowel obstruction			2	7	2	7
Puncture wounds	2	6			2	6
Avulsion, fingertip	2	7			2	7
Breast mass			1	4	1	4
Duodenal ulcer, bleeding			1	12	1	12
Perforated ulcer			1		1	
Hematoma, forearm			1	1	1	1
Cholelithiasis			1	3	1	3
Felon			1	7	1	7
Gangrene of toe	1	29			1	29
Hernia, hiated	1	3	1	3	2	6
Paronychia	1	1			1	1
Hematoma, thigh	1	28			1	28
Traumatic ulcer, leg			1	6	1	6
Hematoma, infected			1	6	1	6
Cellulitis, cheek, staphylococcus			1	2	1	2
Amputation, trauma, left digit			1	2	1	2
Total	97	540	172	563	269	1103
Transfer at Sea	2		4		6	

TABLE A8
Ear, Nose, and Throat Diseases

Diagnosis	1963–1967 Cases	1963–1967 Days	1968–1973 Cases	1968–1973 Days	Total, 1963–1973 Cases	Total, 1963–1973 Days
Pharyngitis	75	197	21	52	96	249
Tonsillitis			23	53	23	53
External otitis	7	31	1	5	8	36
Acute toxic labyrinthitis	6	18	1	1	7	19
Acute sinusitis	3	8	4	6	7	14
Peritonsillar abscess	5	16	2	2	7	18
Otitis media	5	10			5	10
Epistaxis	3	12			3	12
Motion sickness	1	1	2	2	3	3
Traumatic myringotomy			1	4	1	4
Cervical adenitis			1	2	1	2
Meniere's disease	1	1			1	1
Laryngitis	1	2			1	2
Contusion, nose						
Total	107	296	58	130	165	426
Transfer at Sea			1		1	

TABLE A9
Diseases of the Eye

Diagnosis	1963–1967 Cases	1963–1967 Days	1968–1973 Cases	1968–1973 Days	Total, 1963–1973 Cases	Total, 1963–1973 Days
Corneal foreign body	2	8	9	6	11	14
Conjunctivitis	6	14	3	4	9	18
Corneal laceration	5	9	1	5	6	14
Chemical conjunctivitis	1	1	3	3	4	4
Kerato conjunctivitis			3	6	3	6
Orbital burns			2	4	2	4
Iridocyclitis	1	4	1	10	2	14
Corneal ulcer	2	6			2	6
Scald			2	5	2	5
Hyphema	1	21			1	21
Uveitis	1	6			1	6
Nodular epscleritis	1	3			1	3
Periorbital hematoma	1	2			1	2
Corneal abrasion	1	2			1	2
Epicanthal abscess			1	1	1	1
Flash burn	1	1			1	1
Total	23	77	25	44	48	121
Transfer at Sea	1		2		3	

TABLE A10
DISEASES OF THE URINARY TRACT

Diagnosis	1963–1967 Cases	1963–1967 Sick Days	1968–1973 Cases	1968–1973 Sick Days	Total, 1963–1973 Cases	Total, 1963–1973 Sick Days
Ureteral calculi	22	96	17	45	39	141
Epididymitis	12	90	14	63	26	153
Pyelonephritis	12	55	11	34	23	89
Cystitis	4	12	3	19	7	31
Hemorrhagic nephritis			2	2	2	2
Prostatitis			2	11	2	11
Testicular mass			2	2	2	2
Torsion, testes			1	1	1	1
Torsion, appendix testes			1	2	1	2
Urethritis, pneumococcal			1	1	1	1
Hematuria, traumatic			1	1	1	1
Hematuria, urethral angioma			1	6	1	6
Furuncle, penile			1	3	1	3
Abscess, scrotal			1	1	1	1
Glomerulonephritis			2	2	2	2
Hematuria	2	6			2	6
Nonspecific urethritis	1	4			1	4
Hematocele	1	2			1	2
Latent nephritis	1	2			1	2
Total	55	267	60	193	115	460
Transfer at Sea			3		3	

TABLE A11
BONE AND JOINT DISEASES

Diagnosis	1963–1967 Cases	1963–1967 Days	1968–1973 Cases	1968–1973 Days	Total, 1963–1973 Cases	Total, 1963–1973 Days
Lumbosacral strain	31	163	35	306	66	469
Cellulitis of extremity	22	101	23	93	45	194
Ankle sprain	13	40	8	19	21	59
FX metacarpal	5	5	8	28	13	33
Knee sprain	6	22	4	11	10	33
Herniated nucleus pulposus	7	89	2	32	9	121
Torn meniscus	7	59	1	2	8	61
Contusion, extremity	1	4	7	9	8	13
Fracture, finger	1	3	6	10	7	13
Fracture, metatarsal	2	6	4	19	6	25
Fracture, toe	3	14	3	2	6	16
Tenosynovitis	3	14	2	13	5	27

TABLE A11—Continued

Diagnosis	1963–1967 Cases	1963–1967 Days	1968–1973 Cases	1968–1973 Days	Total, 1963–1973 Cases	Total, 1963–1973 Days
Avulsion, amputation			5	8	5	8
Septic arthritis	1	18	3	26	4	44
Ingrown toenail	3	18	1	1	4	19
Fracture, patella	1	15	2	2	3	17
Fracture, ulna			2	3	2	3
Hemarthorsis	1	4	1	10	2	14
Torn lateral meniscus			2	2	2	2
Severed tendon	1	1	1	1	2	2
Sciatica	2	6			2	6
Bursitis, nonspecific separation	2	4			2	4
Acromio-clavicular	2	2			2	2
Fracture, radius	1	1	1	1	2	2
Tenosynovitis, trauma			1	1	1	1
Fracture, rib			1	1	1	1
Fracture, humerus			1	3	1	3
Fracture, nose			1	1	1	1
Supraspinal ligament, strain			1	1	1	1
Spasm, flank			1	3	1	3
Muscle strain, calf			1	6	1	6
Muscle strain, shoulder			1	2	1	2
Ankle edema, bilateral			1	1	1	1
Torticollis			1	1	1	1
L-5 Congenital anomaly, symptomatic	1	14			1	14
Cervical radiculitis	1	14			1	14
Cervical spine pain	1	1			1	1
Hip sprain	1	4			1	4
Foot sprain	1	1			1	1
Bursitis, infra patellar	1	4			1	4
Fracture, tibial tuberosity	1	1			1	1
Fracture, medial malleolus	1	2			1	2
Fracture, thumb with avulsion tip	1	1			1	1
Crush injury, calf	1	3			1	3
Crush injury, foot	1	7			1	7
Knees, stiff	1	2			1	2
Tendonitis, achilles	1	3			1	3
Talo fibular lig., tear	1	2			1	2
Myositis	1	1			1	1
Shoulder dislocation	1	2			1	2
Amputation, index finger	1	13			1	13
Venous stasis			1	1	1	1
Total	132	664	132	619	264	1283
Transfer at Sea	1				1	

TABLE A12
DENTAL PROBLEMS

Diagnosis	1963–1967 Cases	1963–1967 Days	1968–1973 Cases	1968–1973 Days	Total, 1963–1973 Cases	Total, 1963–1973 Days
Periapical abscess	11	36	17	32	28	68
Pericoronitis and peridontitis	5	7	8	6	13	13
Pericoronal abscess			2	2	2	2
Stomatitis	2	14			2	14
Periodontal abscess			1	3	1	3
Caries	1	1			1	1
Pulpitis	1	2			1	2
Salivary calculus	1	1			1	1
Fractured tooth			1	1	1	1
Total	21	61	29	44	50	105
Transfer at Sea			1		1	

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